A Collaborative Model of Science Teacher Professional Development

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Abstract

A goal for most science teachers is to promote students' ability and desire to use scientific information outside of the classroom. The realization of this goal, however, requires not only a general understanding of scientific concepts, but also an understanding of how scientific data and claims are generated. Our team of project scientists and science educators worked with highly skilled high school teachers in a novel professional development program to test hypotheses regarding the association between teaching about how ecological scientists gather evidence and students' broader understanding of the Nature of Science (NOS). In particular, we sought to work with a small group of master teachers to develop a curricular framework for an ecology focused nature of science (ENOS) and associated assessments to determine the extent to which students are able meet framework related goals. To do so, we focused on students' interactions with ecologists and ecological data, and on embedded rubric-based assessments. Teachers were given sole responsibility for addressing the framework within their curricula. Additionally, teachers were asked to conduct an evaluation of the materials they used and to design means by which these materials could be shared with other teachers. Here we describe a novel professional development opportunity, including the partnerships with scientists, and provide evidence regarding the association between this opportunity and changes in teacher practices. Although this work has been conducted with a small number of teachers, the results have implications for future professional development efforts, collaborations with scientists, and the teaching of ENOS.

Keywords

Teacher Professional Development; Case Study; Broader Impacts; Science Education; Ecology

Introduction

The promotion of students' ability and desire to use scientific information in an authentic context is a major goal for science educators and scientists (e.g. National Research Council 2011, Jordan et al. 2009). The realization of this goal, however, requires not only a general understanding of scientific concepts, but also an understanding of how scientific data and claims are generated (i.e., authentic practices, e.g., National Research Council 2011). The ability to integrate these ideas into classroom practice, however, is not easily developed (Ford and Wargo 2007). Further, despite the much efforts have been made by scientists, many educators are not actively engaged in primary scientific investigations, further limiting their ability to provide authentic experiences (Grandy and Duschl 2007).

In order to attract more teachers being engaged in authentic scientific practices, we need to provide quality professional development opportunities and clearly outline instructional frameworks that make scientific epistemology and approaches accessible (Ford and Wargo 2007). Such frameworks should move beyond scientific experimentation, as it is often the norm for teachers (Grandy and Duschl 2007), including broader customs of science. In addition, instruction about epistemic practices might be greatly enhanced by exposure to authentic science and scientists by means of the construction of teacher and scientist partnerships. In turn, scientists often report enjoyment in outreach; a plus, given recent broader impacts imperatives through federal funding agencies (Andrews et al. 2005).

In this paper, a science outreach type of professional development program has been depicted for teachers and its implications has also discussed for educators

and scientists. Our team of project scientists and science educators worked with six highly skilled high school biology teachers in a novel professional development program with the feature of authentic ecological science instruction. The project, supported through a National Science Foundation grant, focused on testing hypotheses on the relationship between teaching how ecologists gather evidence explicitly and students' broader understanding of the Nature of Science (NOS). To make teachers foster this broader understanding in their students, teachers worked in teams with project facilitators and scientists to create a framework of critical ideas associated with the NOS (akin to Lederman et al. 2002). We then aligned these ideas with a series of assessments and classroom practices. All curricular design elements and classroom enactments have been developed by the teachers in order to increase their ability to successfully integrate the materials into their curriculum.

A Professional Development Model

Professional development opportunities that tend to be the most productive for teachers' learning - and ultimately classroom practice - are those that provide them an opportunity to develop content knowledge, promote active learning, and coherent with other classroom activities (Garet et al. 2001). Furthermore, such opportunities should feature supportive collaborations among colleagues, educators and scientists, and are of sufficient duration to allow time for growth and experimentation. There is little in that paper to suggest that teachers need to have classroom interventions designed for them but rather need conceptual stimulation.

The features of productive teacher professional development align with scientist motivations and schedules for outreach (Andrews et al. 2005). If teachers are given sufficient content knowledge and support, then they may be in a position to design curricular interventions. If so, this would allow the scientists to engage in outreach to be able to focus on their area of specialty, the science, while the teachers can focus on their specialty, pedagogy. The resulting conversations could be such that both teacher and scientist as scholars can collaboratively and iteratively shape a classroom intervention over time. There is some evidence for the efficacy of such a collaboration (e.g., Newman and Mowbray 2012), but the model described in prior research is often more time intensive than the program we describe below.

Ecology Nature of Science

Recent work demonstrates that an effective approach in developing a sophisticated understanding of the nature of science (NOS) is to teach science through apprenticeship in the multiple practices of scientists (National Research Council 2011, Duschl et al. 2007). To do so, students need to develop scientific habits of mind that involve theory building, developing and supporting explanations, and using discipline specific means to represent and communicate phenomena. This broad notion of scientific habits of mind is consistent with Schwartz and Martin's interpretive knowing, in which understanding is not a replication of ideas, but a means by which ideas can be applied to solve problems (Schwartz and Martin 2004). It is common practice to teach the generalities of the NOS when teaching any science because these ideas are applied to many scientific disciplines (Schwartz and Lederman 2008).

At first glance, it may not seem necessary to develop an ecology based NOS that is distinct from traditional NOS. Jordan and Duncan, however, found that students are less likely to view ecology as a science in the same manner they would be more lab-based disciplines such as genetics (Jordan and Duncan 2009). In particular, students indicated that different experimental contexts often associated with ecology vs. genetics led them to view methods in ecology as 'less scientific'. As a result, ecological claims were seen as less credible. This suggests a limitation when their thinking of the NOS is applied to ecological studies or current ecological problems, and suggests that students need more rigorous experiences related to ecology.

Jordan et al. outlined critical aspects of habits of mind for ecology, including an understanding of models and inference, uncertainty, and varying temporal and spatial scales (Jordan et al. 2009). Grotzer and Basca found that teaching one aspect of an ecological habit of mind (complex causality) had visible implications for students' understandings, but by developing an intervention targeting students' ideas about causality, student understanding of ecosystems improved (Grotzer and Basca 2003). Along similar lines, Jordan et al. discussed the potential for students who, when given a scaffold to describe an ecosystem through the development of modeling techniques (i.e., another important ecological habit of mind), are more able to understand ecosystem function (Jordan et al. 2009).

In response to students' lack of ecological

understanding and the scientific epistemology behind ecologists' practices, we created a framework for the Ecology Nature of Science (ENOS). Building on the NOS ideas described above, this framework was created by highlighting key ENOS ideas. These ideas are not distinct from generic NOS but rather are posed in an ecological context. It is our belief that the ENOS frame can help students to not only better understand ecology, but also broaden their image of science and NOS understanding.

The work described in this paper engaged teachers in a professional development program which featured monthly conversations with teachers, ecologists, and ecological educators. In these conversations, evidence of ecological understanding rather than curricular development was discussed with the end result being the development of rubrics or lists of benchmark student understandings. These elements were then integrated into the classroom at the teachers' discretion. Using case methodology, below the outcomes have been described from a pilot program where teachers and scientists who formed professional learning communities focused on development and assessment of an ENOS framework for classroom intervention.

Methods

In an effort to describe the context in which our intervention occurred, we applied a case study analysis to determine how the ENOS framework influenced teacher practice, values, and content knowledge. To undertake our intervention, two learning communities, one in New York and one in New Jersey have been created, and each is composed of one of the two project PI's, a senior personnel member (grad student or staff), and three high school teachers. The teachers are master teachers with at least 4 years of experience and all associated with state science teacher societies and formal professional development providers. Because the teachers were working in two groups separated by location (i.e., NY or NJ), we analysed our data as two separate cases.

The structure of our intervention included: formal meetings among members of both learning communities, which occurred twice a year via video conferencing; meetings within each individual learning community, which occurred monthly; and a single week-long summer session with the entire group, which occurred once each year. Our data were obtained from questionnaires completed as part of the intervention during the meetings and individuals shared insight through a phone interview and a focus group with all individuals attendance.

The New Jersey group focused on the use of case study data and embedded rubric, and standards-based assessment on scientific practices. Scientists provided the data, case studies, and expertise in designing assessments of scientific practices. Teachers had sole responsibility for addressing the framework within their curricula. Teachers were also asked to conduct an evaluation of the materials used and to design means by which these materials could be shared with other teachers (see Appendix I).

The New York teachers developed lessons around the context of the 2010 Deepwater Horizon oil spill in the Gulf of Mexico. Lessons included a turtle relocation activity, a wetland study, and outdoor field investigations (river, lake, and/or forest). Teachers used the five key ENOS ideas (ecological understandings) to guide the development of their lessons. The New York teachers and project personnel met every two weeks to discuss assessments and to get updates on lesson implementation and data collection (see Appendix II).

Self-reported Changes Made, Collaborations, Contributions, and Desire to Continue

This paper documents the changes in teacher practice, value, and content knowledge that has occurred in each case. More specifically, we were interested in:

A. Teacher Practices

1. Extent to which teachers infuse or add-on ENOS elements.
2. Teacher-led approaches using:
   Primary/secondary literature, interdisciplinarity, journaling, variables, and sampling errors
3. "Cookbook" vs. no predetermined outcomes
4. Requiring evidence to support explanations
5. Engaging students in Inquiry

B. Teacher Values

1. Ownership and motivation
2. Collaboration
3. Confidence in changes in practice

C. Teacher understanding of NOS/ENOS

Qualitative information was collected from teachers during individual phone interviews and a focus group. This information provided insight into the ways in

which teachers used ENOS ideas and the perceived value of the professional learning community of teacher fellows to shape their understandings of ENOS and their practice. In addition to the qualitative data collection, three surveys were administered: pre-post teacher knowledge of ecology, teacher self-reported changes in practice, and as scientists attended the group sessions, we also collected data opportunistically via a questionnaire addressing scientist self-reported attitudes toward professional development.

Teacher Interviews

An interview protocol was developed by the project evaluator in consultation with all project scientists and science educators. Topics included background information about the teachers and their classes, the way the teachers implemented the ENOS framework, their successes and challenges, and their visions for the future of the project and the ideas it seeks to promote.

Teacher Focus Group

During the summer 2011 meeting, a focus group led by the project evaluator was attended by all six teachers with the goal of more specifically understanding the ways in which involvement in the project and the professional learning community that had been established supported changes in their practice. Focus group questions probed teachers' perspectives regarding the value of the project in terms of its impact on their practice and the specific elements of the professional development opportunity that may have contributed to any of these changes.

Teacher Surveys

Firstly, all teachers were asked to complete a pre and post assessment in which the following key ideas were assessed: (1) whether the nature of science changes among disciplines outside (e.g., physics) and inside (e.g., genetics) the biological sciences, (2) methods, (3) judging validity of claims, (4) evaluating different types of ecological evidence, and (5) the strengths and limitations of arguments related to climate change. Respondents provided ratings and short answer responses. Teacher responses were coded as sophisticated (i.e., containing elements of the expert response) or unsophisticated (i.e., not containing elements of expert response). Such responses tended to be topical and lack complexity. For example when comment on the strengths and weaknesses of data generated through particular methods (e.g., historical accounts, simulations, empirical study) was made, a sophisticated response would discuss the mode in which the data were collected and the expected variability and error associated with this mode, whereas an unsophisticated response would tend to focus on the data collector as not competently collecting the data.

Next, teachers completed a post project questionnaire about what changes the professional development program, which was brought to their classroom and the implications for student learning. In addition, teachers were asked to discuss pros and cons of the program and to comment on how other teachers might get involved. Answers were short essay and responses have been summarized.

Ecologist Survey

To provide a sense of the investment necessary on the part of professionals to contribute to a professional development model like the one described above, we also asked our four professional ecologists a series of questions including: (1) how did this experience compare to any other teacher professional development program with which you may have been involved?; (2) in what way do you think you might have made a difference in the methods by which teachers cover ecology?; (3) did you find the time spent working on the project, pleasant, neutral, unpleasant? why or why not?; and (4) do you have any other thoughts?

Results

Below, our findings have been organized first by description of the interviews and then by summary of the surveys.

Teacher Interview and Focus Group

All teachers infused ENOS ideas into their teaching throughout the school year as opposed to teaching stand-alone ENOS activities. They did so by means of adaptive projects and activities to more directly teach ENOS. They took varied approaches including examining primary and secondary sources, thinking across disciplines (e.g., science and social sciences), having students keep reflective journals, and listing variables and sources of error. In addition, teachers commented that the project moved them beyond "textbook and cookbook labs", allowing students to come up with their own ideas, think through the

nature of evidence and come up with their own conclusions. In addition to changes in their own practice, teachers noted the changes they observed in their students. By engaging in activities that did not have pre-determined conclusions, students developed understandings of ENOS, analyzed scientific evidence, and evaluated information more critically. Teachers reported that the use of primary sources was particularly importantto shape students' thinking.

Overall, teachers highlighted the ENOS ideas and the materials they developed to attract students and encourage them to think critically about the nature of evidence. Teachers especially found the use of primary sources to be beneficial, as well as the rubrics to evaluate those sources. Through close examination of evidence, students were able to more authentically engage in inquiry. In addition, teachers gained a sense of ownership by collaboration with project staff and each other that contributes to their on-going commitment to use ENOS ideas and materials. They valued the partnership with the research centre and the university, including the access to knowledgeable staff and resources that each institution provided. In their own practice, many teachers will continue to employ varied sources of evidence and more authentic inquiry practices, particularly the use of primary sources and methods to evaluate evidence. They plan to continue to think about ways to incorporate the ENOS ideas into other aspects of their curriculum.

Despite the emphasis teachers placed on having developed these more authentic inquiry practices, their recommendations for future work on the project included several mechanisms such as teacher guides or sets of activities that could guide other teachers toward more prescriptive methods. The question of what materials should give teachers so that they may implement ENOS ideas is indeed one of the challenges of the ENOS project, and a challenge more generally of engaging students in developing their own inquiry. It is clear from teachers' responses that they remain committed to continuing this work and considering methods of dissemination and scaling to a broader audience. However, whatever products emerge , this juxtaposition shoud be in consideration, perhaps by emphasizing the ideas rather than the activities and providing resources such as connections to a wide variety of primary sources and rubrics to evaluate.

Though the teachers had incorporated hands on and authentic inquiry in the years prior to the project, teachers explained that by developing their own understandings of ENOS, the PD and professional learning community gave them tools to probe students' understandings and determine students' prior conceptions or misconceptions through more scientifically authentic and complex experiences. As a result, teachers provided less frequent "cookbook" methods to probe students' understandings. They now understand that authentic inquiry includes developing students' understandings of the nature of the evidence, and therefore, they probe students for additional explanations regarding the connections between the evidence and their conclusions. In the past, partially because of state and national standards, they have taught NOS ideas as a set of isolated activities. Now they realize that NOS and ENOS are an integral part of the science that should be infused throughout the curriculum.

Finally, teachers discussed the ways in which the connections to the institutions supported their learning and infusion of ENOS ideas. The collaboration provided a model for them of authentic science, resources in the form of equipment, staff, and primary literature, and as well served as an external motivator for students. Further, the teachers valued the collaborative nature of the process, where they were allowed to develop multi-faceted approaches to teaching ENOS, tailoring their activities to their own teaching style, school, and classroom context. Overall, one teacher described follow-up from project staff, along with the sustained and long-term, content-based, and collaborative nature of the project, as the essential elements of the professional development process.

Teacher Surveys

1) Teacher Knowledge

A total of four teachers provided responses to most questions pre and post intervention. When comment has been made on the general NOS, teachers tended to provide a less sophisticated response post intervention (2/3 (1 blank) coded as sophisticated on pre-test to 1/4 on the post) and this was also true when comment made on ecology with respect to physical science (1/3 (1 blank) sophisticated on the pre to 1/4 post). Increases in sophisticated responses (pre to post intervention), however, were noted for the following: practices of scientists within life sciences (none to 1/2), practice of ecologists (1/2 to all), judging the quality of science (none to 1/2), evaluating claims (1/1 to 1/1), evaluating evidence (1/4 to 1/2), and evaluating

climate change arguments (five questions- none to 1/2, none to 1/2, 1/2 to 3/4, 1/4 to 1/2, and 1/4 to 1/4). With such small numbers it is hard to judge the significance of these changes in frequencies. The general trends, however, seem to support the notion that the teachers experienced modest gains in their understanding of ENOS, but perhaps this is not the case when general NOS is taken into account.

2) *Teacher Self-reported Practice*

A total of four teachers completing the post intervention questionnaire greatly changed their thinking about the NOS, and two of those four greatly changed their thinking about ecology (while the other two had a slight change in their thinking). When asked about how this project influenced their teaching, two individuals reported that this project increased their confidence to teach about ecology while the other two reported that they gained new knowledge. In addition, the opportunity to interact with new teachers and professionals was also mentioned. One teacher added that this project moved her teaching to a more student-cantered practice.

All four cited benefits to teach ENOS in their classrooms: students can interact with authentic data directly from ecologists, students have the opportunity to be more engaged, students have a greater focus on core concepts, and students are part of a more competency-based class as a result of the addition of rubrics and understandings. Teachers also noted some limitations when prompted: time for implementation (3/4 teachers), access to field environments, and experiencing some difficulty in giving up control to students. Positive effects on student learning included the offer of an opportunity to think like a scientist, the gain of more confidence in doing science, interaction with variables, playing a greater role in the scientific process, and to engage with the primary literature. Three out of four teachers believed that the project had no negative impact on student learning while one teacher mentioned that the increased exposure to ecological data resulted in some of her students stating that they no longer enjoyed science. Nonetheless, all four teachers reported that they intend to use the methods learned again, and felt that colleagues could benefit from ENOS professional development. In particular, some ideas for the latter included exposing teachers in other disciplines in the school (e.g., history, math, etc.) to this kind of instruction to encourage team work, encouraging teachers to use models (i.e., as many ecologists do), and providing others with the rubric-based assessments and authentic cases.

Ecologist Survey

All four ecologists found this professional development experience to be different from other experiences. In general this experience was less unidirectional (2/4), involved less preparation (2/4), more abstract (2/4), and thought provoking (1/4). These differences affected teachers getting a view of ecology that is both contemporary (1/4) and realistic (3/4), including insight into key issues such as variability, sociology of science, and uncertainty stemming from primary literature. Finally, all four responded that their experiences with this project were pleasant.

Discussion

After a year and a half of engagement, we found that all six teachers made significant changes in their classrooms. While classroom styles varied, we found that teachers developed considerable collaborations with other teachers and by the end of the project several individuals had shared aspects of their work with colleagues, including at regional meetings. The teachers all spoke highly of the program, and wanted to continue in spite of diminishing resources. Additionally, all teachers felt they had positive evidence of student learning. Lastly, project scientists and science educators felt that the development and enactment of the intervention was reasonable in terms of time spent, valuable in terms of professional growth, and enjoyment.

Key aspects distinguish this professional development program. Very little time was spent on providing the teachers with instruction about ecology. Instead, ecologists and teachers discussed the general Nature of Science and what this means in terms of ecological science. Ideas were shared in terms of case studies and authentic data. In addition, teachers and project directors engaged in discussions about how students might represent their understanding of the Ecology Nature of Science. Assessments were the critical focus of the project, and almost entirely designed by the teachers. It is likely that through this iterative discussion and design project, the teachers also

experienced learning gains about the Ecology Nature of Science.

In spite of the difficult concepts being covered, and the fact that teachers were designing assessments and making curricular changes, teachers reported an increase in confidence. This increasing confidence was not limited only to the presence of the subject matter, but also in their changing mode of instruction as teachers reported a change toward more student-centred instruction. Perhaps the change toward a curricular development program that relied on goals/assessments first (akin to Wiggins and McTighe 2005) resulted in a more conceptual-versus activity-driven classroom. This conceptual focus necessarily places emphasis on student. With clear guidance through assessment, teachers had the flexibility to operate within their comfort zones, yet make changes toward a more student-centred and inquiry-based classroom. Clearly these ideas warrant further testing, but may have implications for the future design of professional development programs.

Essential to the program design process was the ecological scientists. As previously mentioned, time is a limiting factor for many scientists in getting involved with professional development (Andrews et al. 2005). This program, however, required limited time and only asked science and educational professionals for intellectual contributions from their own areas of expertise: ecologists and teachers need only to primarily understand ecology and pedagogy, respectively. In addition, a critical imperative for ecologists is the initiative mounted by federal granting agencies focusing on "broader impacts" (National Science Foundation 2011). These broader impacts involve the development of educational initiatives that expand the impact of the science being funded. Such imperatives put the responsibility of educational professional development in the hands of these scientists who are rarely experts in education. A program described above can enable ecologists to have a large impact without stepping to far afield or dedicating inordinate amounts of time.

In summary, after a year and a half of engagement, we found that all six teachers made significant changes in their classrooms, developed considerable collaborations with other teachers, and had already begun sharing aspects of their work with colleagues teaching other subjects. Although they were given little time and few resources, teachers spoke highly of the program, and all wanted to continue, even with less support. Furthermore, all teachers had positive evidence of student learning.

In conclusion, project scientists and science educators felt that the development and enactment of the intervention was reasonable in terms of time spent, valuable in terms of professional growth, and enjoyment; suggesting that collaborations like the one described above might serve as a viable professional development model for science teachers. This type of professional development is timely given the desire on the part of many scientists to engage in educational outreach. Furthermore, many teacher education programs (R. Jordan pers. obs.) provide a certain level of content expertise (e.g., Life Science specialization as distinct from Chemistry, etc.) which better prepares teachers for more sophisticated content related discourse. Finally, because the intervention is conversation based, there is relatively little financial cost and meetings can be held during evenings, on weekends, or via teleconferencing. Given high benefit to cost ratio, it is recommended that scientists and teachers further explore this type of collaborative professional development program.

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Appendix I

The New Jersey project team, also comprising a diverse group of teachers, developed a series of teacher workshops after beta versions of the ENOS framework and assessments were developed so they could be discussed and edited with teachers' input. Additionally, pilot ENOS assessments were administered toward the end of the school year and semi-structured interviews were conducted and audio-recorded with a subset of 13 students in two of the schools.

December 2009 - Big Ideas

During our first official New Jersey project meeting with teachers in December 2009, four main group topics were covered which included group discussions about: (1) logistics of the project and teacher involvement (2) the NOS, ecology at large and the current state and purpose of scientific education (3) teacher assigned readings (e.g. NOS, ecological and civic literacy) and (4) plans for spring and summer of 2010. Teachers were tasked with developing assessments of ENOS that fit within their existing classroom culture and curriculum before the next teacher workshop.

February 2010 - Teacher ENOS Assessments

Teachers shared the ENOS assessments they had worked on over the last two months with each other and Rutgers researchers. Considerable discussion was focused on the development and revision of scenario-based questions aimed at measuring understanding of ENOS. Assessment questions were discussed and matched to ENOS frameworks. Metrics for assessment were discussed at length.

March 2010 - Revision of ENOS Assessments

Assessment questions which reflected the strengths of individual teachers was refined and finalized during this March workshop. All questions were edited line by line until agreement was reached. The final ENOS assessment included a mix of opinion/perception questions, scenario-based questions, multiple choice and data-driven questions.

May 2010 - Assessment Discussions

Teachers brought in and discussed student impressions of the assessments. Workshop discussion

focused on the pros and cons of the assessment document in its current form and potential room for change. Additionally, teachers discussed student impressions of the assessments.

July 2010 - Summer Workshop

The project PIs (Berkowitz, Jordan, DeLisi), three of the four project senior staff and five of the six project teacher fellows gathered for a two day workshop on July 12 and 13, 2010. The goals of the workshop were to review the results of the student assessments, revisit the ENOS framework and identify the enduring understandings about the ENOS that students should attain. These enduring understandings were based on comments from the CDT and other ecologists about the most critical aspects of our framework, insights from teachers about which aspects of the framework they could or would like to teach, and the results of the student assessment.

August 2010- Summer Workshop part 2

Our project resulted in the following:

Ecosystems: How do ecologists know what they know?

We generated the following: students will discuss the nature of science broadly and how ecosystem science can help people understand the natural world and help people to make decisions. Students will work with their teachers to generate rubrics of what makes a quality ecological investigations (information gathering, analyzing information and drawing conclusions, conducting investigations, communicating ideas, and making decisions). These rubrics will form the basis of assessment during the school year. In addition, throughout the school year, the teachers will use ecological data from primary sources and use their rubrics to determine the affordances and limitations of ecological data. Further, these studies focus on the following topics currently being taught in each class: climate change/carbon cycle, human population growth, local water quality, biomagnification, and disease. The students will also practice using ecological data both by conducting an authentic investigation and by defending personal decisions using support through evidence or personal values (emphasizing the appropriate use of each).

October 2010

Teachers discussed pre-assessments as most were delivered in September. In addition, teachers discussed initial rubric assignments. Teachers made modifications to their rubric assignments.

November 2010

Classroom investigations were planned and teachers discussed peer review articles.

January 2011 online

Once again, rubric assignments were discussed. Investigations protocols were completed.

February 13, 2011

NY and NJ learning communities met for a single day workshop to discuss teachers' final portfolios. In addition, ideas were shared between the two groups. Initial results of the investigation plans were also discussed.

April 2011

Students completed their investigations (some students came directly to Rutgers University while others worked with Rutgers scientists from ecology and from chemistry). An assignment to have students use rubrics to evaluate their investigations was devised.

May 2011

Post assessments were discussed. Final rubric assignments were also discussed and students' investigations were evaluated.

June 27-28, 2011

Teachers met to compile school year work into final portfolios. A web platform was devised.

July 13-14, 2011

New York and New Jersey learning communities met again to discuss final web dissemination of curricular work. In addition, the project PIs and senior personnel met to discuss how the pre-post and formative assessments were to be analyzed. Teachers also outlined trade journal and trade talk outlines to disseminate their work.

Appendix II

Cary Institute of Ecosystem Studies

The three Fellows in the Cary team were selected to represent distinct educational settings: a teacher in an all boys public school in the Bronx, on from a large suburban district and one from a small, rural district. They teach a combination of Living Environment

(New York State's Introductory Biology course) and Environmental Studies/Science.

After an initial meeting to explain the project and the work that was expected of them, we organized monthly phone meetings that focused on discussing parts of their existing curriculum relevant to the NOES framework, developing assessment items and rubrics to analyze student responses, and discussing student thinking as revealed by the assessments and classroom experience.

January 2010

Each teacher piloted approximately seven questions with up to 10 students. During a day-long meeting, we reviewed the student responses and revised the questions accordingly.

March-May 2010

Each teacher selected up to 10 of the revised questions, and administered those questions to 15-50 students.

May 2010 - Ecology Weekend

Teachers and Cary scientists and educators spent a weekend together at our Millbrook campus where we tested, as learners, an instructional model for helping students design an inquiry investigation to learn about the nature of ecological science. During the investigation we grappled with the pros and cons of various types of approaches to ecological investigations, the rigor involved in writing and searching for secondary research, and how to form evidence based claims. The model was very well received by the teachers, and each of them plan to adapt the model and use it with their students during the 2010-2011 school year.

July 12-16, 2010

The project PIs (Berkowitz, Jordan, DeLisi), 3 of the 4 project's senior staff and 5 of the 6 project teacher fellows gathered for a 2 day workshop on July 12 and 13, 2010. The goals of the workshop were to review the results of the student assessments, revisit the NOES framework and identify the enduring understandings about the NOES that students should attain. These enduring understandings were based on comments from the CDT and other ecologists about the most critical aspects of our framework, insights from teachers about which aspects of the framework they could or would like to teach, and the results of the student assessment.

From the set of enduring understandings, we defined specific learning goals that would demonstrate achievement in each understanding and also come up with ideas for instructional models that could achieve the learning goals.

The Cary Institute team continued to meet from July 14-16. During this time, we further articulated the NOES learning goals and began writing lessons for a case study on the Gulf oil spill. The teachers chose this as a case study to center their NOES curriculum because they expect it to generate student interest and discussion, the teachers had all planned to infuse it into their curriculum, and the oil spill curriculum can achieve all of the NOES enduring understandings.

Summer 2010

Kim Notin and NY teachers spearheaded the development of the Enduring Understandings; then

Kim worked with the teachers in developing lessons around the oil spill.

Fall 2010

Student pre-assessments were administered and instruction took place in all teachers'

classrooms.

Winter 2011

- Angelita (Gel) Alvarado replaced Kim Notin and the NY project coordinator based at the Cary. Institute. She met with each member of the NY learning community and resumed in-school support.
- February 13, 2011 – NY and NJ learning communities met for a single day workshop to discuss teachers' final portfolios. In addition, ideas were shared between the two groups. Initial results of the investigation plans were also discussed.

Spring 2011

- The Cary team took the lead at developing and overseeing the implementation of the Riverton Citizenship Activity in teachers' classroom.
- Teachers completed their portfolios, teaching logs and collection of student post-assessments.
- 3/21/11 meeting with NY and NJ team and Beth Covitt to talk about citizenship activity implementation

- 4/14/11 meeting with teachers to follow up their citizenship activity implementation and scheduling interviews with Jackie Delisi (project evaluator)
- 5/16/11 Skype meeting with NY and NJ team leaders and teachers and Jackie Delisi to plan summer meeting

June 25, 2011

All day meeting with teachers to go over

- Update on lesson implementation and data collection
- Get a complete list of lessons/activities teachers have taught in the classroom as part of the project
- Collect student assessments teachers have gathered thus far
- Collect and ask teachers to complete teacher data – content survey, journal log, teaching portfolios
- Brainstorm and develop outlines for papers and products teachers will produce at the July meeting

July 13-14, 2011

New York and New Jersey learning communities met again to discuss final web dissemination of curricular work. In addition, the project PIs and senior personnel met to discuss how the pre-post and formative assessments were to be analyzed. Teachers also outlined trade journal and trade talk outlines to disseminate their work.

July 21, 2011

CDT (Concept Development Team) meeting. The goals of the meeting were:

1. Help the project produce useful and high quality publications
   A. What are the most exciting and important ideas and findings for us to share?
   B. Who are the audiences we should prioritize and where should we publish?
   C. Where should we present papers and/or workshops based on our work?
2. Help shape and make the most of the project's instructional support materials
   A. What are the most exciting and important instructional- and professional development-support products from our project?
   B. Where should these be published or made available, and for what audiences?
   C. How can we best promote their dissemination and use?
3. Provide advice on future directions for our work on teaching the ecology nature of science.
   A. Continuing and/or building on the current project (e.g., as a full implementation DRK-12 proposal)?
   B. Expanding to consider the teaching the socio/environmental nature of science?
   C. Other ideas for continued funding of our work.